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A Simplified Early August Atlantic Basin Seasonal Hurricane Prediction Scheme

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1. Introduction

The Tropical Meteorology Project (TMP) at Colorado State University (CSU) has been issuing Atlantic basin seasonal tropical cyclone (TC) forecasts in early June with an update in early August since 1984 (Gray 1984). While these forecasts have shown moderate skill in real-time (Klotzbach and Gray 2009) (Figure 1), this paper investigates the potential to improve this skill through the development of a new, simplified early August seasonal prediction scheme that uses newer reanalysis data along with forecasts of El Niño – Southern Oscillation (ENSO) from a dynamical model. This paper briefly discusses the results of this new, primarily statistically-based, forecast scheme. Full documentation is available in Klotzbach (2011).

2. Data

All tropical cyclone (TC) data for this project were taken from the National Hurricane Center's "best track" dataset (Jarvinen *et al.* 1984). The target forecast metric is Net Tropical Cyclone (NTC) activity, which is defined to be the sums of the following six parameters: named storms, named storm days, hurricanes, hurricane days, major hurricanes and major hurricanes days, normalized by their 1950-2000 average values. Consequently, 100 NTC units is an average season by definition.

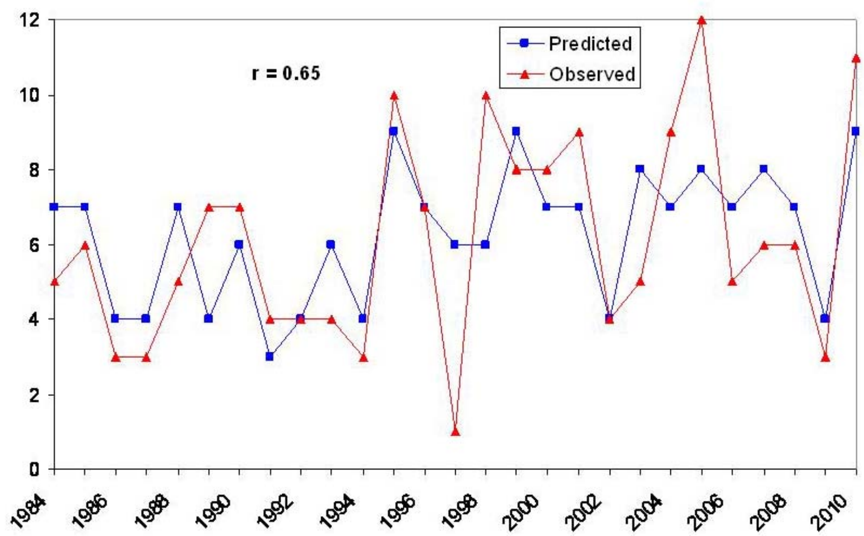

Figure 1 Real-time predicted vs. observed post-31 July Atlantic Basin hurricanes issued by the TMP from 1984-2010.

Large-scale data for the period from 1982-2009 were calculated from the newly-developed Climate Forecast System Reanalysis (CFSR) product (Saha *et al.* 2010). Improved coupling, vertical resolution and data assimilation are generally considered to make the CFSR a more accurate product than its predecessor, the NCEP/NCAR Reanalysis I (Kistler *et al.* 2001). However, the CFSR is currently not available in real-time, so consequently, NCEP/NCAR Reanalysis I products are used to estimate predictor values in real-time forecasts. Testing of atmospheric predictor values prior to 1982 was done using the 20th Century Reanalysis (Compo *et al.* 2011).

Sea surface temperatures (SSTs) from the NOAA Optimum Interpolation SST (OI SST) version 2 are utilized from 1982-present (Reynolds *et al.* 2002). Prior to 1982, SST measurements are calculated from the NOAA Extended Reconstructed SST v3b dataset (Smith *et al.* 2008).

ENSO hindcasts from the European Centre for Medium-Range Weather Forecasts (ECMWF) seasonal forecast system 3 model (Stockdale *et al.* 2011) were provided by Frederic Vitart.

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3. Forecast model development

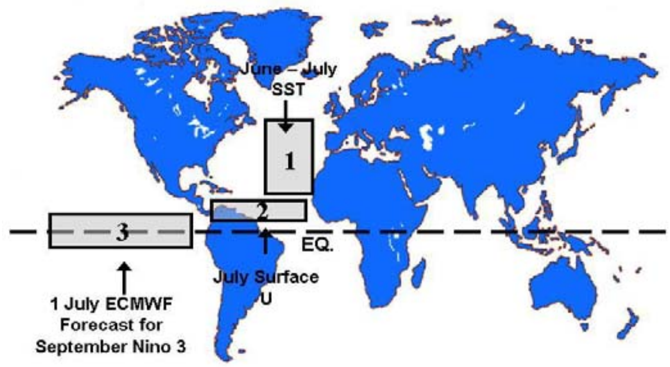

Figure 2 Predictors selected for the new early August statistical forecast model for post-31 July NTC in the Atlantic basin.

Predictors were selected from the CFSR and NOAA OI SST datasets. Precursor signals were investigated during the June-July time period, to find areas that had the strongest correlation with NTC activity over the period from 1982-2009 (the overlapping period for both datasets). Only low-level fields were investigated (*e.g.*, sea level pressure, surface zonal wind), as these predictors were deemed to be more reliable during the earlier part of the 20th century, and the intention was to be able to test the skill of these predictors on earlier-period data. In addition, the ECMWF model's forecasts were examined to determine if they showed significant skill in predicting ENSO from 1 July issue date. The ECMWF model's September forecast for the Nino 3 region (5°S-5°N, 150-90°W) was quite impressive, correlating with observations at 0.90 over the period from 1982-2010. Predictors were only added if they explained an additional three percent of the variance from 1982-2009, and strong physical linkages between each predictor and TC activity were required to have been demonstrated. Each predictor was also required to significantly correlate with NTC over the period from 1982-2009, using a one-tailed Student's t-test. When this predictor qualification procedure was employed, a total of three predictors were selected. These three predictors are displayed in Figure 2.

Predictor Type	Predictor Location	Linear Correlation with NTC (1982-2010)
June-July SST	20-50°N, 35-15°W	0.67
July 10 meter U	10-17.5°N, 80-40°W	0.83
ECMWF September SST Forecast (Model Initialized 1 July)	5°S-5°N, 150-90°W	-0.49

Table 1 Predictors selected for the post-1 August NTC forecast. Also presented are the linear correlations between each individual predictor and post-1 August NTC.

Table 1 displays each predictor's individual correlation with NTC over the period from 1982-2009. All correlations are statistically significant at the 99% level using a one-tailed Student's t-test and assuming that each year represents an individual degree of freedom.

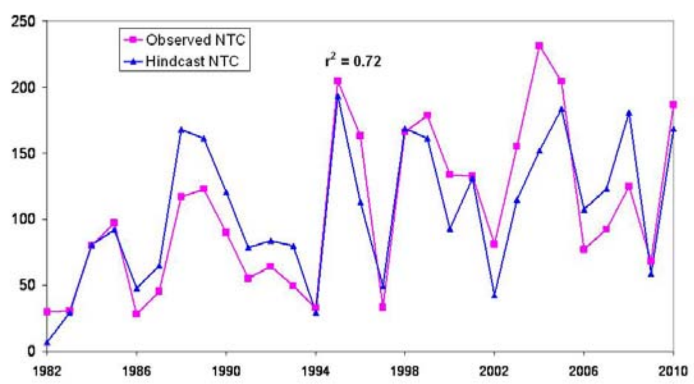

Figure 3 Observed versus post-31 July model jackknifed NTC hindcast over the period from 1982-2010. The three-predictor model explains 72 percent of the variance in post-31 July NTC.

A full discussion of each predictor's individual relationship with NTC is discussed in Klotzbach (2011). All predictors are closely related to either the Atlantic Warm Pool (AWP) or ENSO, which have both been documented in many previous papers (*e.g.*, Gray 1984, Wang and Lee 2007) to have a significant impact on Atlantic TC activity levels, through alterations in large-scale dynamic (*e.g.*, wind shear, low-level vorticity) and thermodynamic (*e.g.*, SST, mid-level humidity) properties.

These three predictors were then combined using linear regression. When they were combined and a drop-one cross validation technique was applied, the linear regression model explained 72 percent of the variability in post-31 July NTC (Figure 3).

4. Earlier period (1900-1981) model verification

The forecast model outlined in the previous section was then examined for similar levels of skill during the earlier part of the 20th century (from 1900-1981). Since the ECMWF forecast model hindcasts are not available prior to around 1980, observed values of the Nino 3 index were used for verification, effectively assuming a perfect ENSO forecast. The ECMWF model correlated with observations at 0.90 over the 1982-2010 period, so assuming a perfect forecast during the earlier part of the 20th century is not too much of a stretch.

Table 2 displays the correlations between each predictor and post-31 July NTC for the 1900-1981 period, as well as the 1900-1947 and 1948-1981 sub-periods, respectively. Correlations are lower than for the 1982-2010 period; however, they remain significant at the 90% level using a one-tailed Student's t-test. In addition, one would expect some degradation in correlation, since both observed large-scale fields (*e.g.*, SLP, SST, low-level wind) as well as TC activity have greater uncertainties associated with them as one goes back further in time.

1900-1981	
Predictor Number (Name)	NTC
1 (Subtropical Atlantic SST)	0.31
2 (Tropical Atlantic U)	0.41
3 (Observed September Nino 3)	-0.32
1900-1947	
Predictor Number (Name)	NTC
1 (Subtropical Atlantic SST)	0.34
2 (Tropical Atlantic U)	0.50
3 (Observed September Nino 3)	-0.46
1948-1981	
Predictor Number (Name)	NTC
1 (Subtropical Atlantic SST)	0.25
2 (Tropical Atlantic U)	0.48
3 (Observed September Nino 3)	-0.25

Table 2 Correlation between predictors and post-1 August NTC over the period from 1900-1981, 1900-1947, and 1948-1981, respectively.

5. New Forecast Model's Improvement upon Klotzbach (2007) Model

This newly-developed forecast model shows modest improvement upon the earlier model developed by Klotzbach (2007). While both models improve significantly upon climatology over the period from 1982-2010, the new model has a smaller mean absolute error than the Klotzbach (2007) model 66% of the time, while also explaining an additional 20% of the variability from climatology (Figure 4).

6. Conclusions and future work

A newly-developed early August statistical forecast model for post-31 July NTC prediction in the Atlantic basin shows significant levels of skill compared against a climatological forecast. The new model utilizes a total of three predictors, which are all closely related to either ENSO or the AWP. The combination of these predictors explains 72% of the variance in cross-validated post-31 July NTC

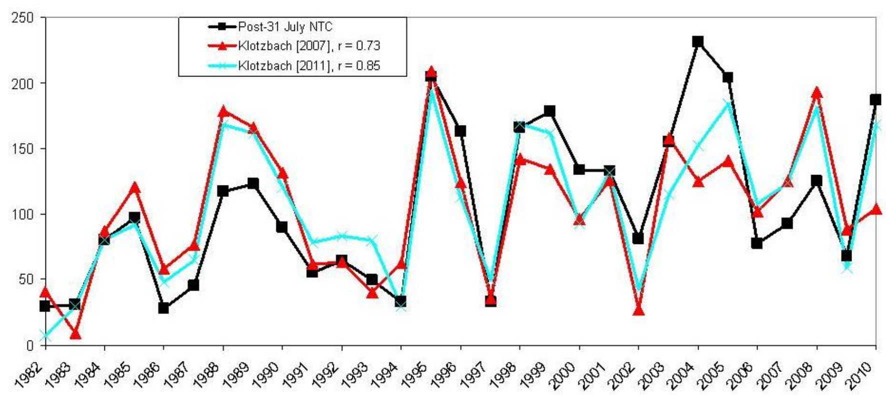

Figure 4 Observed post-31 July NTC (black line), Klotzbach (2007) statistical model forecasts of post-31 July NTC (red line) and Klotzbach (2011) statistical model forecasts of post-31 July NTC (blue line). The Klotzbach (2011) shows improved forecast skill when compared with Klotzbach (2007).

activity.

In the future, additional predictors will be considered including mid-level moisture predictors (such as 500-mb relative humidity). Also, since the ERA-Interim Reanalysis has recently been extended backward to 1979 (Dee *et al.* 2011), this reanalysis product will also be evaluated for forecast development potential.

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